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**Artificial-rearing affects pig emotional state and reactivity**

O Schmitt*[1,2,3] ; K O'Driscoll[1]; EM Baxter[3]; LA Boyle[1]

[1] Pig Development Department, Teagasc Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland

[2] Department of Animal Production, Easter Bush Veterinary Centre, Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Easter Bush Campus, Midlothian EH25 9RG, UK

[3] Animal Behaviour and Welfare Team, Animal and Veterinary Sciences Research Group, SRUC, West Mains Road, Edinburgh EH9 3JG, UK

* Corresponding author: schmitt.oce@gmail.com; (0033)669509464

**Abstract**

Artificial rearing involves removing piglets from their mother at 7 days of age and feeding them milk replacer until weaning. Early-life rearing conditions can influence piglets' mental development, as reflected by their emotional state and reactivity. This study compared the post-weaning emotional state and reactivity of pigs which were either sow-reared (SOW) or artificially-reared (ARTIFICIAL) pre-weaning. Behavioural tests (startle test, novel object test, human-animal relationship test and open door test) were conducted one week post-weaning (weaner 1, 34±0.6 day-old), one week after movement to weaner 2 (69±1.2 day-old) and to finisher (100±1.3 day-old) stages. Qualitative Behavioural Assessments (QBA) were conducted on the same days in weaner 2 and finisher stages. QBA descriptors were computed by PCA and all other data were analysed using linear models. ARTIFICIAL pigs were less fearful of human contact in weaner 1 (45.1 ± 8.43 % vs. 81.3 ± 7.89 %) and finisher (25.8 ± 5.19 % vs. 45.7 ± 6.00 %)stages; but there was no difference in the other tests.

ARTIFICIAL pigs had a higher QBA score (more positive) than SOW pigs in weaner 2 (54.49 ± 10.102 vs. 17.88 ± 9.94) but not in finisher (70.71 ± 8.860 vs. 52.76 ± 9.735) stage. In conclusion, ARTIFICIAL pigs appeared to have a more positive emotional state transiently post-weaning and a lower fearfulness towards humans, which are likely mediated by their pre-weaning conditions. These data emphasize the need to consider the entire life of the animals to fully evaluate the long-term impacts of a rearing system.

**Keywords**

Affective state; artificial rearing; Qualitative Behavioural Assessment; behaviour; human-animal relationship; pigs

## Introduction

Artificial rearing is a management strategy which involves removing piglets from their mother and transferring them to a specialised enclosure where they are fed milk replacer until weaning (Baxter *et al.* 2013). Removing offspring from their mothers before the recommended weaning age at an early age, typically within the first 7 days of life, raises ethical concerns (for further discussion see Rutherford *et al.* 2011). Artificial rearing is relevant because of the increased prevalence of large litters on pig farms and because it removes the need for several nurse sows in a "cascade fostering" strategy (for more details see Baxter *et al*. 2013). Artificial rearing removes the risk of piglet mortality due to crushing by the sow and could potentially increase piglet growth rates because milk replacer is fed *ad libitum*. However, there are contradictory results about the effects of artificial rearing, with some studies reporting positive effects on growth (Cabrera *et al.* 2010; van Beirendonck *et al.* 2015) and others not (De Vos *et al.* 2014; Schmitt *et al.* 2019) prior to weaning. Where there are pre-weaning advantages in growth, artificially-reared pigs seem to lose them post-weaning and have lower carcass quality than sow-reared pigs (Cabrera *et al.* 2010; De Vos *et al.* 2014). Other differences in artificially-reared piglets include performance of more aggressive and biting behaviours pre-weaning (Rzezniczek *et al.* 2015; this study: Schmitt *et al.* 2019), compared to sow-reared piglets. This behavioural difference potentially reflects a lower ability to cope with the system. Thus artificially-reared pigs might not cope with post-weaning conditions as well as their sow-reared counterparts, although this has not yet been investigated from a welfare perspective.

Artificial rearing involves maternal deprivation from a very young age, which is likely to impair the behavioural development of piglets. In particular, neurological consequences of stress might impair pigs' cognitive abilities (learning and memory) and behavioural organization processes (Poletto *et al.* 2006), given the link between stress levels and cognitive abilities (Lupien *et al.* 2009). A decreased expression of genes regulating glucocorticoid response in the hippocampus was observed in early-weaned piglets (10 days of age), compared to non-weaned piglets (Poletto *et al*. 2006), which might indicate a reduced ability to down-regulate the hypothalamic pituitary adrenal axis function (Poletto *et al.* 2006).. In rodent work, repeated maternal deprivations during lactation (i.e. 180 min daily from post-natal days 2 to 14) altered the central corticotropin-releasing factor systems in rat pups, which potentially exacerbated their response (high levels of plasma adrenocorticotropic hormone and corticosterone) to a psychological stressor (air puff startle) as adults (Plotsky *et al.* 2005). Therefore, it can be hypothesised that maternally-deprived pigs would also show a greater reaction to a stressor than non-deprived counterparts, and this higher sensibility to stress may result in a less positive emotional state.

Assessing an animal's emotional valence and emotional reactivity is a way to evaluate its emotional state and thus, its welfare status (Fraser *et al.* 1997; Boissy *et al.* 2007). The Welfare Quality Protocol (Welfare Quality® 2009) for pigs includes a Qualitative Behavioural Assessment (QBA) of the animals, to evaluate their emotional state's valence, as part of the estimation of the overall welfare level on farms. The QBA involves observing a group of pigs and then scoring the prevalence of pre-defined descriptors. These descriptors have either a positive valence (e.g. happy, content, enjoying) or a negative valence (e.g. bored, aimless, frustrated), and are meant to reflect an animal's experience of a situation (Wemelsfelder & Lawrence 2001). The computation of the descriptors' values and weights gives an overall index/score which can be used to compare the valence of animals' emotional states A number of other tests, such as the human approach test, open door test etc., were validated for assessing different types of emotional reactivity in a commercial setting (e.g. Brown *et al.* 2009). Assessing the emotional reactivity of an animal to an experience  is useful in assessing its welfare (Koolhaas & Reenen 2016) since the results inform on how stressful was their experience.

Artificial rearing systems are quite novel but already used on some commercial farms. Therefore, there are gaps in the scientific knowledge about the long-term impacts of artificial rearing on the welfare of older pigs that need to be addressed in order to conclude on the acceptability of the system. This study investigated the effects of artificial rearing on pigs' emotional state and reactivity post-weaning.

## Material and Methods

### ***Ethical approval***

Ethical approval for this study was granted by Teagasc Animal Ethics Committee (application TAEC113/2016). The experiment was carried out in accordance with the Irish legislation (SI no. 543/2012) and the EU Directive 2010/63/EU for animal experiments.

### ***Animals and experimental design***

This experiment was conducted from April to December 2016 on a commercial farm in Co. Laois, Ireland, and involved a total of 233 piglets from 20 litters. The genetic background of the piglets was Large White x Hampshire, or Landrace x Hampshire. During gestation, sows were loosed-housed in groups (120 sows per pen), and fed once a day. Details of the housing and management of the animals pre-weaning are described in Schmitt *et al.* (2019). Briefly, all piglets were born in a conventional farrowing pen (2.13 x 1.71 m, stocking density for 12 piglets: 0.27 $m^2$/piglet) fitted with a sow crate (1.90 x 0.64 m) and with a slatted floor. Litters matched for piglet weight, age (7 days of age) and size (n = 11.7±0.2 piglets) were selected for inclusion in the study, over 10 replicates. One litter remained with the sow until weaning (sow-reared, SOW; n = 10 litters, n = 116 piglets) and the other was transferred to an artificial-rearing enclosure (1.40 x 0.71 m, stocking density for 12 piglets: 0.08 $m^2$/piglet, fully slatted floor; Rescue Deck®, S&R Resources LLC) and fed milk replacer (Opticare Milk, SwiNco BV, The Netherlands) until weaning (artificially-reared, ARTIFICIAL; n = 10 litters, n = 117 piglets). The artificial rearing enclosures were fitted in a dedicated room, at approximately 0.50 m high. Piglets were weaned at approximately 27 ± 0.4 days of age. Weaning was defined as the removal of milk feeding and movement of the piglets to weaner accommodation (see below for details). It was routine practice on the farm to group pigs according to weight and rearing system at weaning. Hence recruited piglets were mixed with other non-experimental pigs from the same neonatal environment (i.e. either farrowing pen or artificial-rearing enclosure) and of the same age at weaning.

At weaning, all piglets were moved to the first-stage “weaner 1” accommodation (average weight: 7.65 ± 0.088 kg; average stocking density: 0.17 ± 0.05 $m^2$/pig). Pigs were moved to the second stage “weaner 2” accommodation (average weight: 23.06 ± 0.359 kg; average stocking density: 0.30 ± 0.03 $m^2$/pig) and to the “finisher” stage accommodation (average weight: 47.83 ± 0.359 kg; average stocking density: 0.51 ± 0.14 $m^2$/pig), at about four and eight weeks post-weaning, respectively. At weaner 1 stage, there were 11 pens of ARTIFICIAL pigs and 13 pens of SOW pigs; at weaner 2 stage, there were 15 pens of SOW pigs and 18 pens of ARTIFICIAL pigs; at finisher stage, there were 11 pens of SOW pigs and 17 pens of ARTIFICIAL pigs. At each movement, pigs were re-mixed but only within treatment group, and focal pigs (i.e. all pigs from the experimental litters) were kept together as much as possible, with additional pigs from the same rearing strategy added to the group to make up the numbers in the pen. Even though pen dimensions differed within the same stage, pigs from both treatments were housed in the same type of pen at each stage, therefore the effect of pen dimension and stocking density was controlled. Stocking densities presented here correspond to the situation at the time of data collection. Legal stocking densities were maintained during the production cycle by splitting groups.

***Nutrition***

Details of the pre-weaning diets are in Schmitt *et al.* (2019). In brief, ARTIFICIAL piglets were fed milk replacer containing 21.5 % crude protein and 9% fat, and dried porcine plasma powder, while SOW piglets were fed sow milk (natural nursing).. Both SOW and ARTIFICIAL piglets had access to creep feed from 7 to 22 days of age, and pellets from 22 days of age until 5 days post-weaning. The weaner diet was provided from 5 days post-weaning (approximately 15 kg) until the pigs entered the finisher stage (approximately 50 kg); and contained 17.5 % crude protein, 4.09 % crude fat and 3.75 % crude fibre, for a net energy of 9.8 MJ/kg. Finisher diets contained 16.55 % crude protein, 3.70 % crude fat and 4.24 % crude fibre, for a net energy of 9.7 MJ/kg.

***Measurements***

All data were collected on the same days, relative to the pigs' stage of life. Figure 1 describes the timeline of the experimental procedures carried out (behavioural test and qualitative behavioural assessment).

*Behavioural tests*

Pigs were subjected to behavioural tests one week after movement to weaner 1 (34 ± 0.6 day-old), weaner 2 (69 ± 1.2 day-old) and finisher (100 ± 1.3 days-old) accommodation. The 1-week delay between transfer to each production stage and testing was to ensure that the pigs had habituated to their new physical and social environment. Pigs were marked with livestock markers, at least an hour before the tests were conducted, to allow identification of focal pigs. The four tests were performed consecutively, in the same order (to standardise testing procedure; Ison *et al.* (2015)) on the same day for each group of pigs..

**Startle test (ST).** The startle test provided a measure of the animals' reaction (i.e. startling) when a sudden event occurred, and of their capacity to recover from the startle. Upon entering each room, the observer walked to and stopped in front of the farrowing pen/artificial-rearing enclosure, then opened a red umbrella while facing the pigs and starting the timer. The startle reaction of pigs was scored (score 1 = at least 60% of pigs startled in the group; score 0 = no startling reaction or less than 60% of the group startled). Startling was defined as the pigs stopping their activities and being immobile for at least a second. In startled groups, the latency of pigs to start behaving "normally" (i.e. walking, resting, eating) without fleeing or looking at the observer was also recorded.

**Novel object test (NOT).** Immediately after the startle test, the experimenter attached a novel object to the centre of the wall on one side of the pen and then dropped it into the pen. Pigs were free to interact (i.e. bite, lick, sniff, rub, chew) with the novel object for 5 min, after which it was removed (as per Brown *et al*.(2009) and Kooij *et al*. (2002)). The latency for the first pig to interact with the novel object was recorded and gave a measure of the group fearfulness of the novel object. The novel object was changed between test sessions as follows:

- Weaner 1: Yellow plastic Frisbee, 23 cm diameter
- Weaner 2: Pink plastic spade, 32.5 cm long x 9 cm large
- Finisher: Blue plastic bucket, 14.5 cm diameter x 14 cm high

**Human-animal relationship tests (HART).** After the NOT, two human-animal relationship tests (HART) were conducted to measure fearfulness of humans. The first test (HART1) measured the group reaction to the presence of human and the second test (HART2) measured the fear response of each focal pig to human contact. For the HART1, the experimenter entered the pen and scored the 'panic response' of the pigs (fleeing or facing away from the human or huddling together in a corner of the pen) as described in Welfare Quality® (2009) (score 0 = up to 60% of the pigs show panic response; score 1 = more than 60% of pigs showed panic response). Directly after HART1, all experimental pigs within a pen were submitted to the HART2 and the order of testing depended on the ease of access to the focal pig. The procedure of HART2 was adapted from the human fear test of the Welfare Quality® protocol for sows and is detailed in Figure 1. Pigs showing fear reaction at any human approach stage received a score of 1 and pigs accepting human contact were scored 0. If at any point the pig moved away from the experimenter due to interruption or distraction, apparently unrelated to fearfulness (e.g. another pig interfered with the assessment), the experimenter followed the focal pig to another location and continued the test from the beginning of the interrupted stage. If a pig moved away three times in succession, although not apparently fearful, it was scored as "withdrawing" for that stage. The experimenter was familiar to the pigs as she observed and handled them regularly pre-weaning (Schmitt *et al.* 2019) and marked them before the tests were conducted.

**Open door test (ODT).** The procedure of the open door test (ODT) followed the description by Brown *et al*. (2009) and assessed the pigs' motivation and fear to exit the pen and explore a novel environment (the corridor). Following the two HARTs, the experimenter opened the pen door and remained silent, standing next to one side of the pen, visible to the pigs. Pigs were allowed to exit the pen during the 3 min duration of the test. The latency for the first pig to exit, and the number of pigs that left the pen at 1 min, 2 min and 3 min after opening the door were recorded.

### *Qualitative Behavioural Assessment*

Qualitative Behavioural Assessment (QBA) was performed as described in the Welfare Quality® assessment protocol for pigs (Welfare Quality®, 2009). Pigs were assessed one week after movement to the weaner 2 (69 ± 1.2 days-old) and finisher (100 ± 1.3 days-old) stages, before the behavioural tests were performed. Groups of pigs were directly observed for 20 min after which the experimenter scored the 20 fixed descriptors on a 125 mm horizontal valence scale. Details of the calculation of the QBA score can be found in the Welfare Quality® Protocol (Welfare Quality® 2009).

### ***Statistical analyses***

Statistical analyses were performed using SAS 9.4 (SAS Inst. Inc., Cary, NC). The experimental unit for the analysis was the pen. General Linear Models (GLM) and Generalized Linear Mixed Models (GLMM) were fitted using the Residual Pseudo Likelihood approximation method. Statistically significant terms were determined when alpha was below 0.05. Replicate and number of pigs in the pen were included as random effects in all models. As groups were not stable over time, data were analysed for each stage separately. Back-transformed values are reported where transformation of data was made to fit normal distribution.

Startle scores and HART1 were analysed using GLMM (PROC GLIMMIX) with a binary distribution and a logit link function. Since no ARTIFICIAL pigs reacted in ST at finisher stage and in HART1 at weaner 2 stage, these data were analysed using Kruskal-Wallis non-parametric tests (PROC NPAR1WAY). Since no SOW or ARTIFICIAL pigs reacted to human in HAR at finisher stage, these data were not analysed. Latencies to recover normal activity (ST), to approach the novel object (NOT), and to exit the pen (ODT) were normally distributed and analysed with GLMs (PROC MIXED). The maximum percentage of pigs seen out of the pen (ODT) was normally distributed and analysed using GLMs (PROC MIXED).

QBA scores were analysed using GLM (PROC MIXED) accounting for the random effect of replicate and pen. Principal Component Analysis (PCA) was performed on the descriptor scores to obtain principal components explaining the variability in QBA score between treatments. The first two principal components with eigenvalues above 1.0 were retained to produce a two-dimensional word chart, where the 20 descriptors' eigenvector values (i.e. quantification of the weight of the descriptor) were plotted on the two principal components axes. Each group of ARTIFICIAL and SOW pigs received a score on each of the two main principal components, which allowed defining clusters.

## Results

### ***Behavioural tests***

There was no effect of treatment on the group reaction in ST at weaner 1 (SOW: 79.9 ± 13.53 %, ARTIFICIAL: 84.3 ± 12.50 %, $F_{1,14} = 0.08$, $P = 0.7$) and weaner 2 (SOW: 46.7 ± 19.34 % , ARTIFICIAL: 51.2 ± 20.36 %, $F_{1,6} = 0.03$, $P = 0.8$) stages, but at finisher stage no ARTIFICIAL pens startled while pigs in SOW pens did (0.0 ± 0.00 % vs. 50.0 ± 22.36 %, respectively; $X^2_1 = 4.73$, $P < 0.05$). The latency to recover to normal activity after the startling stimulus was not different between treatments in weaner 1 stage (11.6 ± 3.10 s vs. 18.5 ± 3.04 s, respectively; $F_{1,15.6} = 3.66$, $P = 0.07$) and in weaner 2 stage (10.7 ± 2.52 s vs. 18.1 ± 2.54 s, respectively; $F_{1,1.07} = 68.05$, $P = 0.07$). As ARTIFICIAL pigs did not startle in finisher stage, the analysis of the latency to recover was not relevant.

The results of the NOT were not different between SOW and ARTIFICIAL pigs at weaner 1 (7.5 ± 2.89 s vs. 10.4 ± 3.14 s, respectively, $F_{1,22} = 0.44$, $P > 0.5$), weaner 2 (1.6 ± 0.39 s vs. 1.6 ± 0.41 s, respectively, $F_{1,15} = 0.02$, $P > 0.9$), and finisher (3.0 ± 2.01 s vs. 1.7 ± 2.14 s, respectively, $F_{1,2.99} = 0.33$, $P > 0.6$) stages.

In the HART1 the percentage of pens showing a fearful reaction to human presence was not different between ARTIFICIAL and SOW pigs at weaner 1 (79.6 ± 26.99 % vs. 14.37 ± 22.32 %, respectively; $F_{1,14} = 3.95$, $P = 0.06$) and at weaner 2 (22.2 ± 14.70 % vs. 0.0 ± 0.00 %, respectively; $X^2_1 = 1.90$, $P > 0.1$) stages, and none of the SOW or ARTIFICIAL pens reacted to human presence at finisher stage. In the HART2 the percentage of pigs fearful of human contact was lower in ARTIFICIAL pigs than in SOW pigs at weaner 1 (45.1 ± 8.43 % vs. 81.3 ± 7.89 %, respectively; $F_{1,20.1} = 10.1$; $P < 0.005$) and finisher (25.8 ± 5.19 % vs. 45.7 ± 6.00 %, respectively; $F_{1,12} = 6.28$; $P < 0.05$) stages, but not at weaner 2 (31.4 ± 10.37 % vs. 44.0 ± 10.72 %, respectively; $F_{1,13.2} = 1.05$; $P > 0.3$) stage (Figure 2).

During the ODT, the maximum percentage of pigs seen out of the pen did not differ between ARTIFICIAL and SOW pigs at weaner 1 (62.5 ± 6.14 % vs. 77.9 ± 5.79 %; $F_{1,20.1} = 3.93$; $P = 0.06$), weaner 2 (81.6 ± 2.93 % vs. 88.4 ± 2.76 %; $F_{1,15} = 2.87$; $P > 0.1$) or finisher (73.1 ± 7.48 % vs. 82.8 ± 8.36 %; $F_{1,6.86} = 1.05$; $P > 0.3$) stages (Figure 3). The latency to exit the pen after the door was opened was not different between SOW and ARTIFICIAL pigs, either at weaner 1 (14.2 ± 15.19 s vs. 34.1 ± 16.52 s, respectively; $F_{1,22} = 0.78$, $P > 0.3$), weaner 2 (4.9 ± 1.47 s vs. 3.75 ± 1.56 s, respectively; $F_{1,15} = 0.28$, $P > 0.6$), or finisher stage (9.6 ± 6.32 s vs. 10.2 ± 6.30 s, respectively; $F_{1,4} = 0.23$, $P > 0.6$).

***Qualitative Behavioural Assessment***

ARTIFICIAL pigs had a higher Qualitative Behavioural Assessment (QBA) score than SOW pigs at weaner 2 stage (54.49 ± 10.102 vs. 17.88 ± 9.941, respectively; $F_{1,12.8} = -13.01$, $P < 0.005$), but not at finisher stage (70.71 ± 8.860 vs. 52.76 ± 9.735, respectively; $F_{1,19.5} = 10.08$, $P > 0.2$).

At weaner 2 stage, the PCA identified two principal components, or axes, along which the pigs were perceived: "axis 1" explained 33.6 % of the variation in QBA score, and "axis 2" explained 16.7% of the variation in QBA scores (Figure 4a). The descriptors which best defined (eigenvector value above or below 0.25) "axis 1" were lively (0.32), enjoying (0.32), content (0.31), happy (0.27), relaxed (0.26), calm (0.25), fearful (-0.34), tense (-0.32) and distressed (-0.27) (Figure 4a). The descriptors which best defined "axis 2" were bored (0.42), positively occupied (0.36), sociable (0.31), playful (0.27), happy (0.25), indifferent (-0.31) and calm (-0.25) (Figure 4a). SOW pigs had lower loadings than ARTIFICIAL on "axis 1" but the two treatments did not differ in their loadings on "axis 2" (Figure 4b). Therefore, groups of ARTIFICIAL pigs were perceived as more enjoying, lively, content and happy, and less fearful, tense and distressed, compared to SOW pigs.

At finisher stage, the PCA identified two principal components, or axes, along which the pigs were perceived: "axis 1" explained 39.2 % of the variation between treatments in QBA score, and "axis 2" explained 16.3% of the variation between treatments in QBA scores (Figure 5a). The descriptors which best defined "axis 1" were content (0.30), playful (0.30), happy (0.27), calm (0.27), enjoying (0.26), tense (-0.33) and frustrated (-0.28) (Figure 5a). The descriptors which best defined "axis 2" were relaxed (0.36), aimless (0.36), listless (0.35), bored (0.33), indifferent (-0.28), active (-0.35) and fearful (-0.28). The clustering of group of pigs according to their loadings on "axis 1" and "axis 2" is not clear (Figure 5b), probably because there was no treatment difference in QBA score. Only two groups of SOW pigs singularly had very low loadings on "axis 1". Therefore, they were perceived as more frustrated and tense, and less content, playful, happy, calm, and enjoying, than the other groups of pigs, independent of whether they were ARTIFICIAL or SOW pigs.

**Discussion**

The results of this study confirmed that pre-weaning rearing conditions are associated with transient differences between pigs in their post-weaning emotional state and emotional reactivity. Indeed, differences in emotional state and emotional reactivity to behavioural tests were found at the first two post-weaning stages, but not at finisher stage.

ARTFICIAL pigs were less reactive to humans (HART1 and HART2) and to a sudden event (ST), at least numerically. Therefore, ARTIFICIAL pigs were likely not as stressed as SOW pigs in the presence of the farm staff, or when exposed to sudden movement or noise. SOW pigs seemed to habituate gradually to human presence, since the number of pens with a fearful reaction to human presence (HART1) decreased across the rearing period, while ARTIFICIAL pigs maintained their low level of human fear across time. However, the percentage of pigs fearful of human contact (HART2) remained (at least numerically) higher in SOW pigs, compared to ARTIFICIAL pigs, throughout the rearing period. ARTIFICIAL and SOW piglets likely had different experiences with humans during the pre-weaning period as the two rearing environments were quite different and required slightly different management. For instance, as the artificial-rearing enclosures were elevated (i.e. at waist level), the stockperson was able to lift the lid of the enclosure to directly access the piglets for health checks and to administer treatments. In contrast, to do the same for sow reared piglets in farrowing pens they would need to step into the pen. This difference would also have influenced the handling of the piglets such that ARTIFICIAL piglets could easily be caught and lifted from a waist height whereas SOW piglets had to be pursued to be caught and then lifted from the ground. This association of human presence with negative events may have heightened the SOW piglets' fear of humans. Furthermore, piglets can attempt to escape in farrowing pens but not in artificial rearing enclosures because the former are more spacious. This inevitably prolongs the time taken to conduct husbandry procedures thereby further increasing stress levels (Hemsworth 2014; Marchant-Forde *et al.* 2014). ARTIFICIAL piglets had limited space to escape and this shortened the time taken to catch them and therefore reduced the likelihood of developing a negative relationship with humans. Fear of humans might be transmitted amongst individuals in the room through social transmission (i.e. where an animal imitates another's behaviour, Nicol 1995), or by emotional contagion(i.e. a simple form of empathy; Reimert *et al.* 2013; Goumon & Špinka 2016). There are examples of piglets learning behaviours from pen mates and the sow (e.g. vertical social learning of feeding behaviour; Oostindjer *et al.* 2011) and although transmission of fear behaviours has not, to our knowledge, been studied specifically between sows and piglets it is a possible factor to be considered when discussing this result. Recently, a study by Tallet *et al*. (2016) demonstrated that transmission of emotional experience with humans occurs between the sow and the piglets during gestation, and that this influences the reactivity of piglets to human voices during lactation. Social transmission of human fear by the mother would be expected to be more pronounced in SOW piglets, since ARTIFICIAL piglets only had contact with the sow during their first seven days of age. The study of Zupan *et al*. (2016) suggested that regular gentle handling, even if it represented a mild stressor for some piglets, could promote positive behaviours such as locomotor play; increased play was observed in litters where half of the piglets were handled, compared to non-handled litters (Zupan *et al.* 2016).

The emotional state of ARTIFICIAL pigs was more positive than SOW pigs at the weaner 2 stage but not at the finisher stage. During the direct observations for QBA scoring at weaner 2 stage, ARTIFICIAL pigs were perceived as more 'enjoying', 'lively', 'content' and 'happy', and less 'fearful', 'tense' and 'distressed' than SOW pigs. This was in spite of the close proximity of the observer and so could partly be explained by the ARTIFICIAL pigs being more relaxed and comfortable in the presence of humans. Since the stocking density pre-weaning was higher for ARTIFICIAL than for SOW piglets, the switch to post-weaning housing represented a dramatic increase in space allowance for ARTIFICIAL, but not for SOW pigs. Consequently, this change in environment that could be seen as a challenge to pig welfare could have been experienced as a positive change by ARTIFICIAL pigs, since their environment actually improved, which could explain their better emotional state in the weeks following weaning. This is supported by studies on environmental enrichment showing that removal of pre-weaning enrichment at weaning was detrimental to piglets' post-weaning welfare (Melotti *et al.* 2011; Brajon *et al.* 2017), while moving from barren to enriched environment likely improved their welfare (Melotti *et al.* 2011). This is without considering that SOW pigs were just removed from their mother, which is a negative experience, while ARTIFICIAL pigs already experienced separation from their mother three weeks before.

Since ARTIFICIAL pigs had a better emotional state and a lower emotional reactivity in most behavioural tests in the first two post-weaning stages, compared to SOW pigs, our results seem to suggest better welfare status in ARTIFICIAL pigs compared to SOW pigs in the post-weaning period. Generally this represents a period of very poor welfare for pigs (Weary *et al.* 2008) because of the abrupt separation from their mother, a change in diet, and changes to the physical and social environment. Our results could be interpreted as artificial rearing somewhat mitigating the negative effects of weaning. However, this study should not be used to assert that artificial rearing improves pig welfare by reducing a negative response to weaning conditions, but rather that this system creates an ambiguous situation where welfare improvements may be consequences of previous welfare impairments. In a study involving the same pigs prior to weaning, behaviour and growth of ARTIFICIAL piglets during the pre-weaning period was significantly negatively affected relative to SOW piglets (Schmitt *et al.* 2019). Furthermore these post-weaning effects are only transient, as ARTIFICIAL and SOW pigs did not differ in their emotional state or in their emotional reactivity at the finisher stage, and the current study does not consider other aspects of pig welfare such as health status, or level of damaging behaviour. Therefore, more detailed studies, including measures of health and frequent behavioural observations, should be conducted in order to add knowledge on the long-term effects of artificial-rearing.

## Conclusion

### *General conclusion*

In conclusion, the results of this study show that the pre-weaning rearing conditions of piglets have transient effects on their post-weaning emotional state and reactivity. However, when considering the results of this study, one must be very careful in their interpretation. Artificial rearing is unlikely to have improved the overall welfare status of the animals substantially, but rather to have lowered the welfare of piglets so much before weaning (Schmitt *et al.* 2019) that they did not experience weaning to be as of a negative experience as SOW pigs. These findings also stress the need to consider the development of an animal's welfare through its whole life in order to be able to draw conclusions on the overall welfare status, which has implications for the acceptability of a(n) (artificial) rearing system and for its improvement.

### *Animal welfare implications*

This is the first work investigating the impact of artificial rearing on aspects of the welfare of pigs post-weaning, namely their emotional state and reactivity. The results suggested that ARTIFICIAL piglets had a better welfare status post-weaning, as weaning represented a relative improvement in their environment. However this does not mitigate the negative welfare experienced by ARTIFICIAL pigs in the pre-weaning period. This highlights the need to consider the whole life of the animals to properly interpret data and make conclusions on the welfare impacts of a rearing system.

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Conflict of interest = none.

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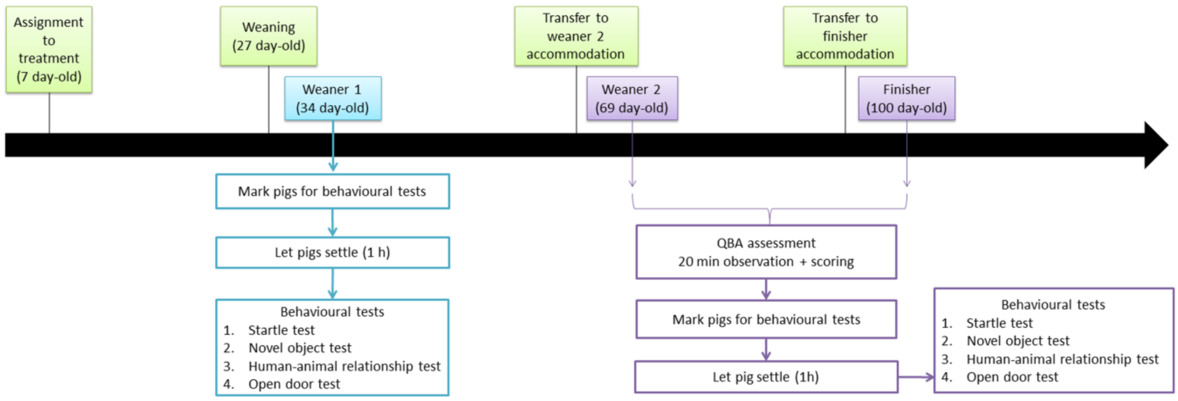



**Figure 1** Graphical representation of the timeline of the experimental procedures.

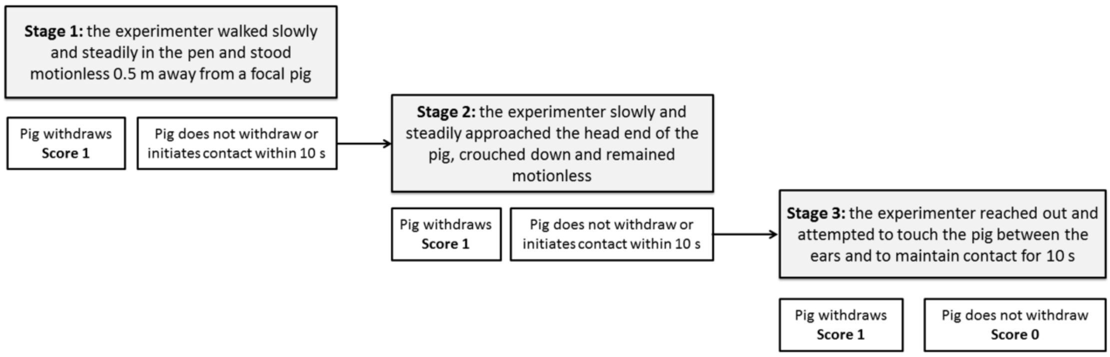



**Figure 2** Schematic representation of the second human-animal relationship test (HART2) procedure and scoring, adapted from the Welfare Quality® protocol for sows (Welfare Quality® 2009).

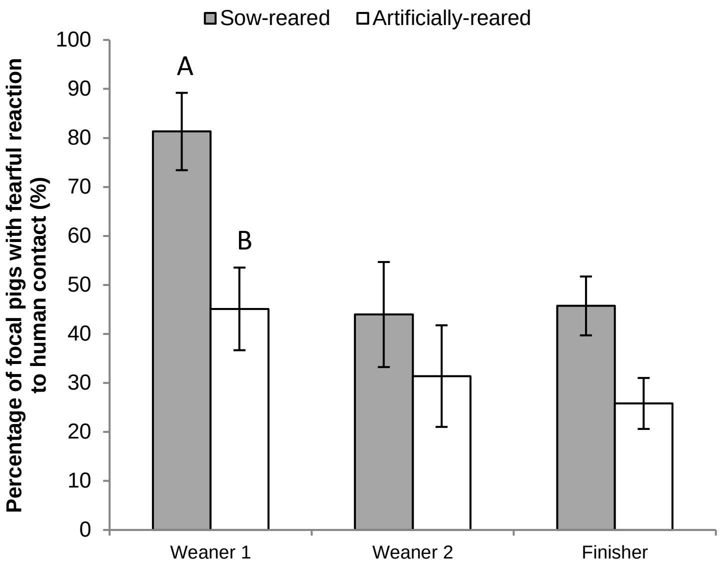
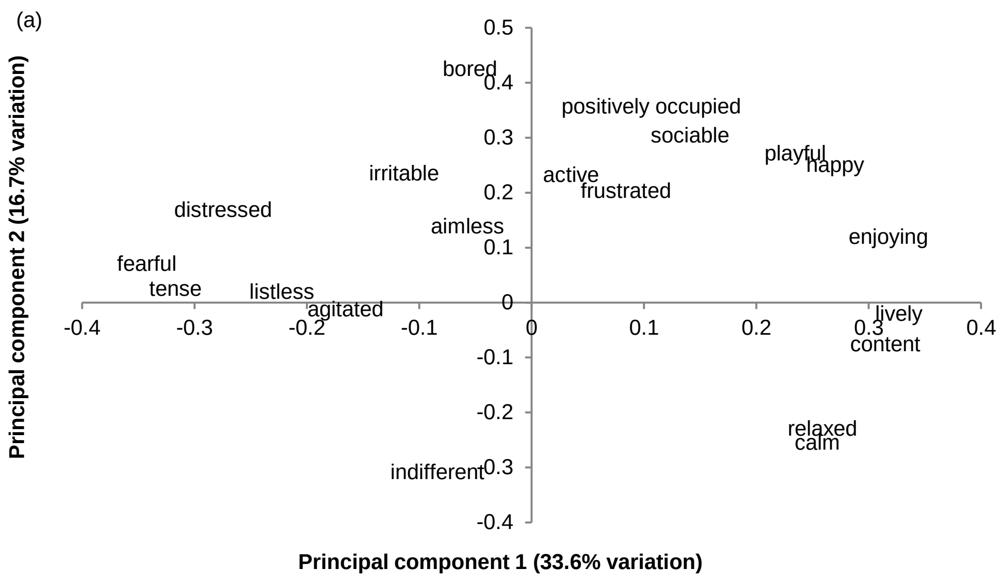



**Figure 3** Mean (±S.E.) percentage of pigs showing a fearful reaction to human approach and contact during the second human-animal relationship test (HART2). Pigs were either sow-reared (SOW) or artificially-reared (ARTIFICIAL) pre-weaning. Post-weaning conditions were similar for both treatments. Pigs were tested during weaner 1 (34 ± 0.6 days-old), weaner 2 (69 ± 1.2 days-old) and finisher (100 ± 1.3 days-old) stages. Superscript letters indicate differences between treatments within each stage of post-weaning period ($^{a,b}$ P<0.05; $^{A,B}$ P<0.005).



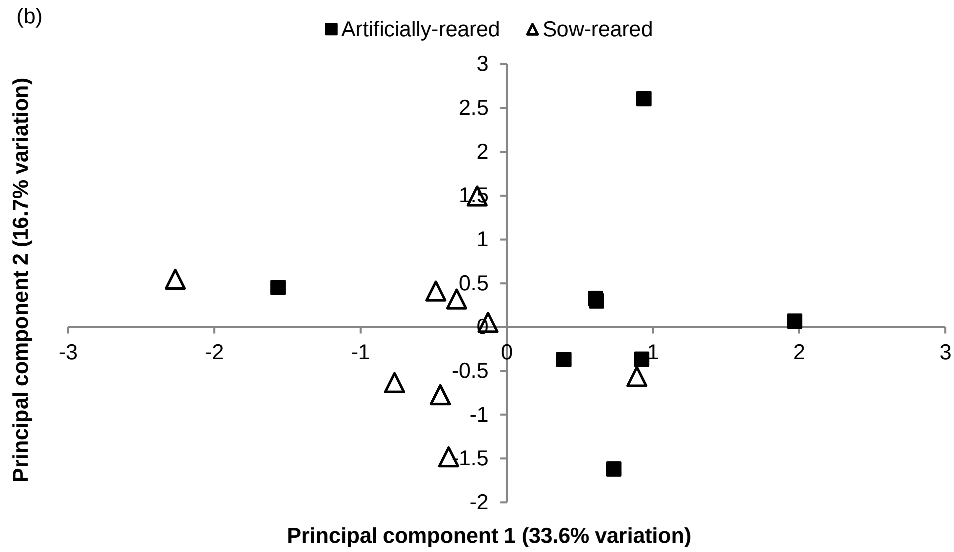
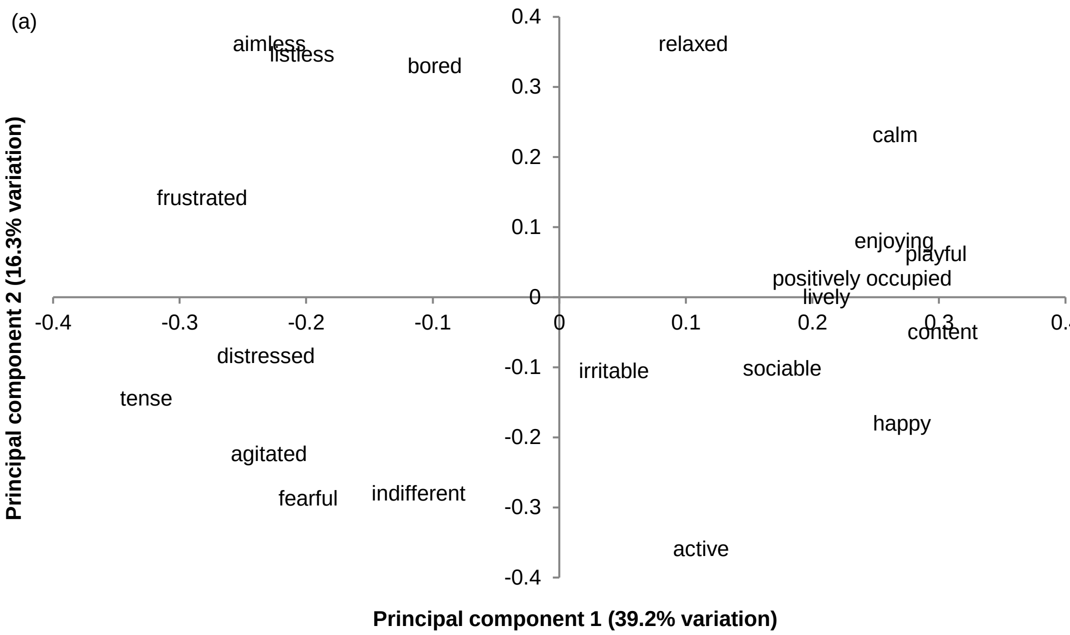




**Figure 4** Graphical representation of Principal Component Analysis (PCA) outcomes for Qualitative Behavioural Assessment (QBA) at weaner 2 stage (68.7±1.3 days-old). Observed pigs were either artificially-reared (removed from their mother at 7 days of age and fed milk replacer until weaning; ARTIFICIAL) or sow-reared (remained with mother; SOW).

a) Eigenvector values of each descriptor on the two principal components, or axes, retained from the PCA. “Axis 1” represented 31% of the total variation of QBA score, and “Axis 2” represented 19% of the total variation of the QBA score.

b) Loadings of the ARTIFICIAL and SOW groups of pigs along the two principal components.



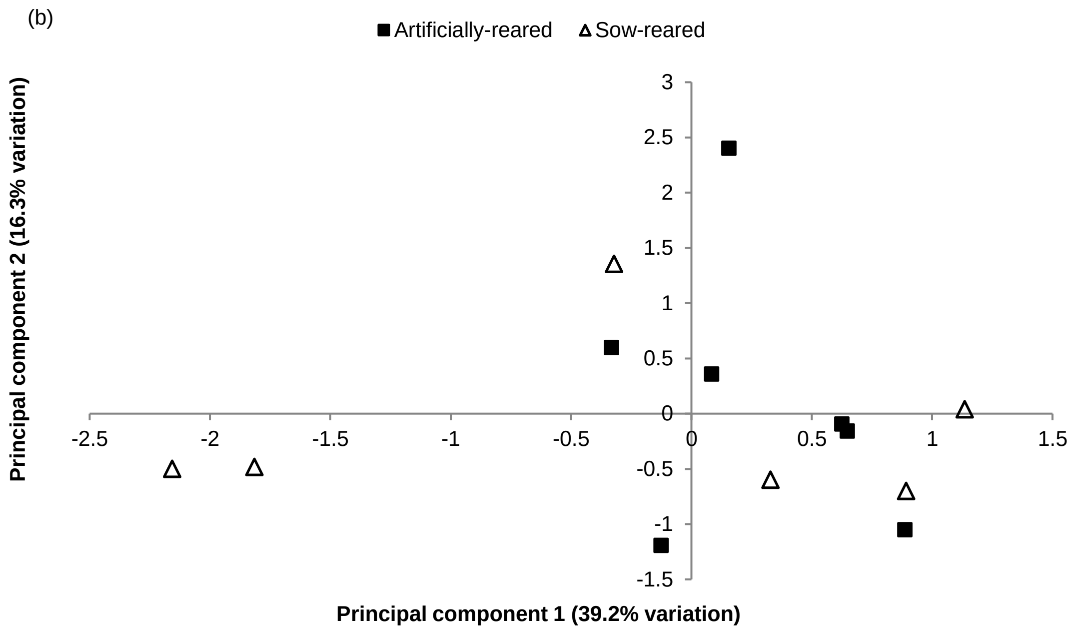




**Figure 5** Graphical representation of Principal Component Analysis (PCA) outcomes for Qualitative Behavioural Assessment (QBA) at finisher stage (100.1±1.2 days-old). Observed pigs were either artificially-reared (removed from their mother at 7 days of age and fed milk replacer until weaning; ARTIFICIAL) or sow-reared (remained with mother; SOW).

a) Eigenvector values of each descriptor on the two principal components, or axes, retained from the PCA. “Axis 1” represented 41% of the total variation of QBA score, and “Axis 2” represented 14% of the total variation of the QBA score.

b) Loadings of the ARTIFICIAL and SOW groups of pigs along the two principal components.